Community features of *Indocalamus wilsoni* in the Shennongjia National Nature Reserve, China

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Abstract: Four vegetation types, namely coniferous and broadleaved mixed forest, secondary deciduous broadleaved forest, open shrubs and meadow, with dwarf bamboo (*Indocalamus wilsoni*) are compared on their floristic composition, life form, community structure, and survivorship of bamboos. Disturbance of conifer-logging two decades ago promoted the species diversity, but negatively influenced the survivorship of dwarf bamboo which is dominate on the forest floor. Open shrubs bear more species diversity and more geophytes in its life-form spectrum than its background vegetation subalpine meadow, however, dwarf bamboo is growing much better in the open shrubs than in the meadow. It seems dwarf bamboo probably favorites to occur in the vegetation at gentle slopes with a mediate canopy cover. Its mass flowering in the secondary deciduous forest suggests that a simultaneous flowering and following dieback maybe irrupt in the recently coming years over the subalpine Shennongjia in China, which will be not only alter the floristic composition and community structure of the old bamboo stands, but also influence the survivorship of this rare species.

Key words: Indocalamus wilsoni; Community structure; Survivorship
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Introduction

Dwarf bamboo, *Indocalamus wilsoni* (Rendle) C. S. Chao et C. D. Chu (Syn. *I. nubigenus* (Keng f.) Yi ex H. R. Zhao et Y. L. Yang), is a rare species which discretely endemics in the subalpine belt of the Shennongjia National Nature Reserve (110°03'05"-110°33'50" E, 31°21'20"-31°30'20" N) with an elevation ranged from 1 700 m up to 2 500 m (Zhu *et al.* 1994; Zheng 1993; Zhu *et al.* 1999). As a monocarpic plant, it usually forms dense understorey, with a height varied from 0.5 to 1.2 m, of forest and shrubs or extends into the meadow to form bamboo mosaics. The life history of many subalpine bamboos is characterized by an unusual flowering habitat. They often flower to die simultaneously over a wide area after vegetative reproduction for several decades (Qin 1985; Yi 1988; Campbell 1987; Campbell 1991; Tian 1991; Wang *et al.* 1991; Taylor *et al.* 1992; Makita 1992; Taylor & Qin Z. S. 1996; Zhou & Huang 1996). This die back is an endogenous disturbance that might promote tree seedling establishment and alter community structure, composition or both. Meanwhile, the existing community structure and composition should influence the bamboo regeneration thus may shift the vegetation in the old bamboo stands.

We noted in September 2000 that dwarf bamboo started to mass flowering in a secondary broad-leaved forest and about 30%-50% of bamboo culms in the stand had already withered away. To protect this rare species and observe its regenerative process after flowering and the future succession of its associated vegetation, an ecological study is immediately needed since there is no any ecological attention have been given to this bamboo species yet. This study is attempted to demonstrate the present community features of bamboo stands on the aspects of floristic composition, life form, cover structure, and survive situation of this dwarf bamboo.

Study area

The Shennongjia National Nature Reserve, located at the western terminus of the Daba mountain range on the northern-west border of Hubei Province, comprises 70 467 hm^2 of steep rugged mountains and elevations that range from 480 m to 3 105.4 m. The extreme topographic relief coupled with the elevation range provides habitats for an incredible diverse flora and the climatic conditions that extend from northern subtropics through cold temperate (Zhu *et al*, 1999; Ban *et al.* 1996). The zonal climate in Shennogjia is a transitional type of the north subtropical and the warm-temperate moist monsoon, controlled mainly by subtropical circulation, but there is a complex climate gradient that corresponds to elevation, however the dwarf bamboo *Indocalamus wilsoni* occurs only from 1 700 m to 2 500 m along the elevation. In this belt, with the increase of altitude, the mean annual temperature varies from 7.4°C to 4.8°C and annual precipitation increases from about 1 800 mm up to 2 500 mm.

After a general vegetation survey, the ecological investigation of dwarf bamboo was carried out in four selected

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sites: Small Qianjiaping (GPS location: 31°23'336"N, 110°24'476"E, Alt. 2040 m), Qianjiaping (31°23 '345"N, 110°24'500"E, Alt. 1990 m), White-Water Valley (31°27'704"N, 110°09'489"E, Alt. 2300 m) and Tiger Ditch (31°27'648"N 110°09'528"E Alt. 2450 m). These sites respectively represented four main community types of dwarf bamboo in the Shennongjia National Nature Reserve: a) bamboo under coniferous and deciduous broad-leaved mixed forest (Small Qianjiaping), b) bamboo under deciduous broad-leaved forest (Qianjiaping), c) bamboo within subalpine open shrubs (White-Water Valley) and d) bamboo in subalpine meadow (Tiger Ditch).

The Small Qianjiaping plot (Plot A as blow) was located on a gently rolling slope of a mountain floor, and the Qianjiaping plot (Plot B) was located on the same mountain at a concave slope (Table 1). Both plots face an alluvial basin which was covered by hygrophytic grasses from the genera of *Carex, Junicus* and *Scirpus* and scrubs such as *Salix carprea* var. *inica, Crataegus wilsoni, Lespedeza Formosa* and *Prunus szechuanica*. The original mountain vegetation type on this region belongs to the coniferous and broadleaf mixed forest (Ban 1995), but most of this forest formation in this area had been destroyed due to heavy logging of *Pinus armandii* in 1970s and early 1980s before the establishment of the nature reserve. Plot A is an easily accessible site where Dwarf bamboo is keeping in the original mixed forest, and Plot B. represents the ecological features of the bamboo in the disturbed community of deciduous broadleaved forest. We set up Plot B also because the bamboo here is starting to mass flower, and a further observation will be carried on at this site.

Table.1. Environmental characteristics of the *Indocalamus wilsoni* stands

Plot	Slope	Aspect	Alt. (m)	Landform	Soil type	Veg. type
Small Qianjiaping (A)	15º	S40ºE	2040	Floor slope	Brown soil	Forest
Qianjiaping (B)	35º	S70ºE	1990	Concave slope	Brown soil	Forest
White-Water Valley(C)	25º	S15ºW	2300	Ridge slope	Dark-brown soil	Shrubs
Tiger Ditch (D)	5º	N60ºE	2450	Crest terrace	Meadow soil	Meadow

White-Water Valley plot (Plot C) and Tiger Ditch plot (Plot D) situated at the south part of the reserve. Here tectonic uplift and fluvial erosion have produced a deep incised topography in the landform. Slopes are steep (30-70o), but the crests and terraces of the mountain are relatively plain. Where the vegetation is quite complex and poorly understood. Most of steep slopes are covered by secondary vegetation of deciduous broad-leaved forest with arrow bamboo (*Fargesia* spp.) as the understorey, while the original dominant conifer *Abies fargesii* remains at the deep valley. Open shrubs and meadow are relatively stable vegetations, which occupy the upper plateaus with arrow bamboo clumps. Dwarf bamboo frequently occurs as density understorey of the open shrub or as mosaic within the meadow. White-Water plot (Plot C) and Tiger Ditch plot (Plot D) show the ecological characteristics of the draft bamboo in these two community types.

Methods

All field data were collected between September 2000 and April 2001. Four representative plots were selected after an overall observation in the reserve. In each plots, we set up a 20 m×20-m quadrat to quantify the upper storey. All living trees and high-shrubs taller than 2 m in height were numbered, their heights, subaxle heights, diameters at breast height (DBH), and crown projection were measured. In the 20 m×20-m quadrat, we also set up several 2m×2-m sub-quadrats for recording understorey and 1m ×1-m sub-quadrats for recording the draft bamboo *Indocalamus wilsoni* and herbs. Of each species in the understorey and herb layer the height, coverage, dominance, and life form (using Raunkiaer's system) were noted. A particular attention was given to the bamboo on its community features.

Life form spectra were calculated based on the cover-abundance rate for each species on a 5-points scale and each is assigned a sociability index (Moore & Chapman, 1986), also derived from a 5-point scale: 1- Growing once in a place, singly; 2- Grouped or tufted; 3- In troops, small patches or cushions; 4- In small colonies, in extensive patches or forming carpets; 5- In great crowds or pure populations. The floristical similarity between plots based on presence/absence data of species was calculated using the Similarity Index of Sørensen (ISs): ISs=W/(A+B)×100%, where W is the number of common species and A and B the number of species in plot A and B respectively. To compare the species diversities among the plots, Shannon index and McIntosh's index (Kent, 1996) were calculated for each plot.

For understanding the relationship between the canopy cover and the survivorship of dwarf bamboo, a detailed cover profile for each individual stand was presented, and the living situation including height, density, cover of bamboo was analyzed.

Results

Floristical composition and diversity

There are 38 dominant species were checked out in our four plots, which allocated in Plot A, B, C, and D are 15, 22, 24 and 18 respectively. The floristic similarity (Table 2) shows that Plot C and D are very similar in species composition (ISs as high as 0.71), and Plot A and B are also

similar in the floristic aspect (ISs = 0.65), while Plot A and D are very different in the species composition (ISs = 0.24). It suggests that the floristic feature has not changed dramatically when zonal mixed forest (Plot A) degraded to deciduous broad-leaved forest (Plot B) in the past two decades, and open shrubs (Plot C) has a tightly floristic connection with its backgrounds vegetation of meadow.

Table 2. Sørensen similarity index of species in dwarf bamboo stands of Plot A, B, C and D

	A	B	C	D
A		0.35	0.54	0.76
B	0.65		0.57	0.65
C	0.46	0.43		0.29
D	0.24	0.35	0.71	

Note: Down-left section shows the similarity (ISs) and upper-right section shows the difference (D= 1 – ISs)

Although all stands are rich in species comparing with the coniferous -- arrow bamboo (*Fargesia* spp) formation at the same altitude (Li 1994), the difference of diversity between stands is quite clear. Both Shennon's and McIntosh's indices shows that the species diversity of the open shrubs (Plot C) is the highest, the meadow ranks (Plot D) the second highest, and the secondary deciduous forest (Plot B) and the original mixed forest (Plot A) rank as the third and the forth respectively (Fig. 1 & 2). The diversity indices indict only a slight difference between plot A and Plot B, but their floristic compositions are very different. In Plot B, when conifer *Pinus armandii* was cut down, the sun-like species *Betula albo-sinensis, Populus davisina, Acer mono* developed as the over-storey and *Lindera obtusiloba, Crataegus wilsoni, Cotoneaster acutifolius, Viburnum ichsngense* developed as the sub-storey (Table 3). Usually the logging gaps created an opportunity to the establishment of both conifers and broad-leaved trees (Taylor 1990; Taylor *et al*, 1996; Li 1996; Shotaro *et al*, 1998), but in Plot B the dense understorey of bamboo I. wilsoni may reduce seedling success of conifers on the ground since we checked no seedlings of *P. armandii* in our quadrats. There is no clear difference of the ground herbs between Plot A and B, which are dominated by some shade-tolerance species such as *Smilacina japonica, Rubia cardifolia, Oxalis grtffithii, Paris quadrifolia* and ferns (*Dryopteris* sp. and *Pteridium* sp.).

The open shrubs (Plot C) are remarkably rich in species, however its overstorey is usually composed by several common species such as *Malus huphensis, M. kansuensis, Sorbus huphensis,* and *Crataegus wilsoni*. We noted that S. huphensis can reach as high as 20 m at low altitude although it performances as a shrub with height only about 2-4 m in the area above 2200 m. There is no distinctive boundary between open shrubs and subalpine meadow (Plot D) in our study site since individual shrub clumps are frequently distributed in the meadow and species composition of the understorey of open shrubs is nearly as same as that of the meadow which is mainly composed by grass species of *Arundinella hirta, Deyeuxia henryi, Imperata cylindrical, Carex* spp, and herb species such as *Polygonum suffultum, Geranium henryi, Paris quadrifolia, Allium prattii, Smilacina japonica,* as well as several fern species

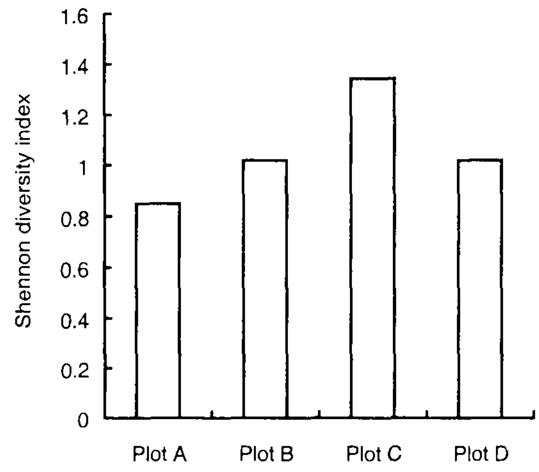

Fig. 1. Shennon diversity index of species in *I. wilsonii* stands.
It shows Open shrubs (Plot C) > Meadow (D) > secondary deciduous forest (B) > mixed forest (A)

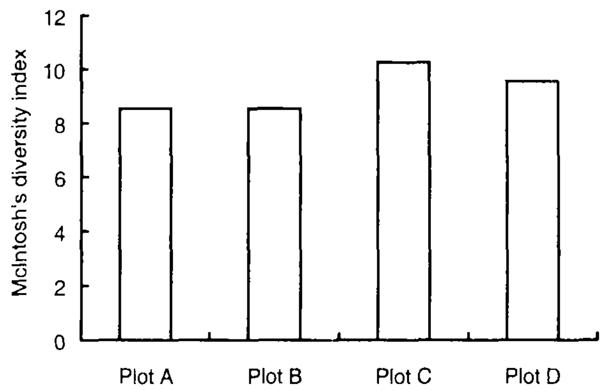

Fig. 2. McIntosh's diversity index of species in I. wilsonii stands.
It shows Open shrubs (Plot C) > Meadow (D) > secondary deciduous forest (B) = mixed forest (A)

Life form and cover structure

The life form spectra (Fig. 3) show a similarity between mixed forest and deciduous broad-leaved forest. The above-ground phytomass in Plot A and B are made up for over 40% by phanerophytes, as against 20% in open shrubs (Plot C) and 6% in meadow (Plot D). Nevertheless the higher proportion of phanerophytes in Plot B than in Plot A suggests that the logging disturbance has enhanced the recruitment of trees and shrubs. In Plot C, phytomass is mostly dominated by Geophytes (38%), which is clearly different from its background vegetation of meadow (Plot D). The latest plot is mostly dominated by hemicrypto-

phytes (37%).

In subalpine Shennongjia, where a thick cover of snow protects the rhizomes of dwarf bamboo and the bulbs of bulb species such as *Smilacina japonica*, *Paris quadrifolia*, and *Allium prattii* from the damage of frost, all of our plots are considerably rich in cryptophytes which survive the cold winter with buds or shoot apices below ground. Although Fliervoet classified the giant bamboo (*Phyllostachy pubescens*) as phanerophytes (Fliervoet *et al.* 1989), we placed the dwarf bamboo in the context of geophytes mainly because its new shoots emerge in the next growing season only from the underground winter-buds of the rhizomes. The dominance of geophytes on the open shrubs also suggests that the shrub canopy positively influenced the distribution of the geophytes and negatively on the hemicrytophytes.

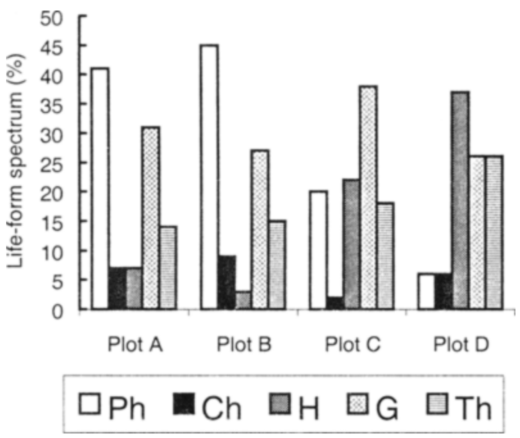

Fig. 3. Life form spectra of the stands of *Indocalamus wilsonii* based on the abundance-cover scales of each species. Ph = Phanerophytes, Ch = Chamae-phytes, H = Hemicryptophytes, G = Geophytes, Th = Therophytes

The vertical structure of mixed forest in Plot A consisted three layers: canopy (higher than 8 m), bamboo and scrubs (8-0.5 m), ground-herbs (lower than 0.5 m). Fig. 4A shows the coverage distribution of each layer from the main species. Conifer *Pinus armandii* covered about 28% of the stand area, while three main broad-leaved tree species *Salix polyclona, Chaenomeles cathayensis* and *Prunus szchuanica* covered 31%, 26% and 14% respectively. Considered the canopy overlap, we estimated that the real canopy coverage is about 60%. The understorey is absolutely dominated by I. wilsoni which covered over 90% of forest floor in our quadrats. Under the dwarf bamboo layer, the thin herbs covered only 20% of the ground. Comparing with Plot A, the vertical layers in deciduous broad-leaved forest of Plot B are not very clear (Fig. 4B), but it can roughly be calculated as four layers: canopy, shrubs, bamboo and ground herbs. Three most dominate deciduous tree species *Betula albo-sinensis, Populus daviviana* and *Acer mono* covered 38%, 20% and 16% of the stand respectively with the height between 10 m and 20 m. The real canopy coverage is about 85%, which means the canopy in Plot B is much closer than in Plot A. The shrubs are usually high 2 to 6 m, where they formed a sub-canopy with a real coverage of about 30%-45%. Bamboo layer covered 70-80% of forest floor, and among it 30-50% are withered culms after flowering. We noted in the gaps and forest margins, the bamboos are still alive quite well. It suggests that the dense canopy maybe trigged the flowering of Indocalamus, or at least, shorted its life cycle. Since the dieback of Indocalamus, more herbs are inversing in the bamboo stands so that 30%-40% ground was covered by the herbs.

Like the mixed forest in Plot A, the open shrubs in Plot C also contain three layers: shrub layer (3-8 m), bamboo layer (0.4-0.8 m) and herbaceous layer (5-40 cm). Total canopy cover of shrub layer is about 30%, which is mainly formed by three common species of *Chaenomeles cathayensis, Sorbus huphensis* and *Malus kansuensis* (Fig. 4C). The understory layer covered about 90% of the stand floor, in which Indocalamus contributed with 60% of the total cover, while the other 40% came from perennial grasses and ferns. The meadow is usually considered as a mono-layered vegetation types, but in plot D, its canopy is formed by three clearly separate strata (Fig. 4D): upper grass stratum (0.6-1.8 m), bamboo stratum (0.3-0.6 m), and low herbaceous stratum (5-30 cm). The upper stratum is dominated by some typical meadow grasses in subalpine Shennongjia: *Arundinella hirta, Imperata cylindrical* and *Trisetum henryi*. The total cover of upper grasses is about 35% against the stand, and bamboo stratum and low herbaceous stratum presented the coverage as 80% and 25% respectively. In the bamboo layer *I. wilsoni* contributed 50% of the canopy, and the ferns are poorly represented in this stratum.

Discussion

In our study site of Shennongjia, the survivorship of dwarf bamboo closely responded to the composition, structure, and canopy cover of its associated vegetation. Forest canopy density has a strong influence on the growth of bamboo. In the Plot A, where with a mature forest canopy small-intermidediate-sized canopy gaps had taller bamboo with greater coverage than beneath tree crowns of Plot B (Table 3). This indicts the disturbances of conifer logging in the bamboo stands probably promoted the recruitment of trees and shrubs, which formed a denser canopy, and then the closed canopy reduced the annual growth of new bamboo culms that sprout once every year from its underground rhizome. During the past two decades the mean height of bamboo layer in the forests has reduced from 80-95 cm in Plot A to 40-65 cm in Plot B, and the coverage also reduced from 90%-95% to 60%-80%.

On the other hand, bamboo grew much weaker in the meadow without upper canopy than under open shrubs

with large gaps. The mean height of bamboo layer in the open shrubs lower than in both of the mixed forest and the secondary deciduous broad-leaved forest may be explained by variation of altitude since Plot C is located about 400 m higher than that of Plot A and B. Thus our investigation suggests that Indocalamus very favorites in the vegetation occurred at gentle slopes with a mediate overstorey canopy.

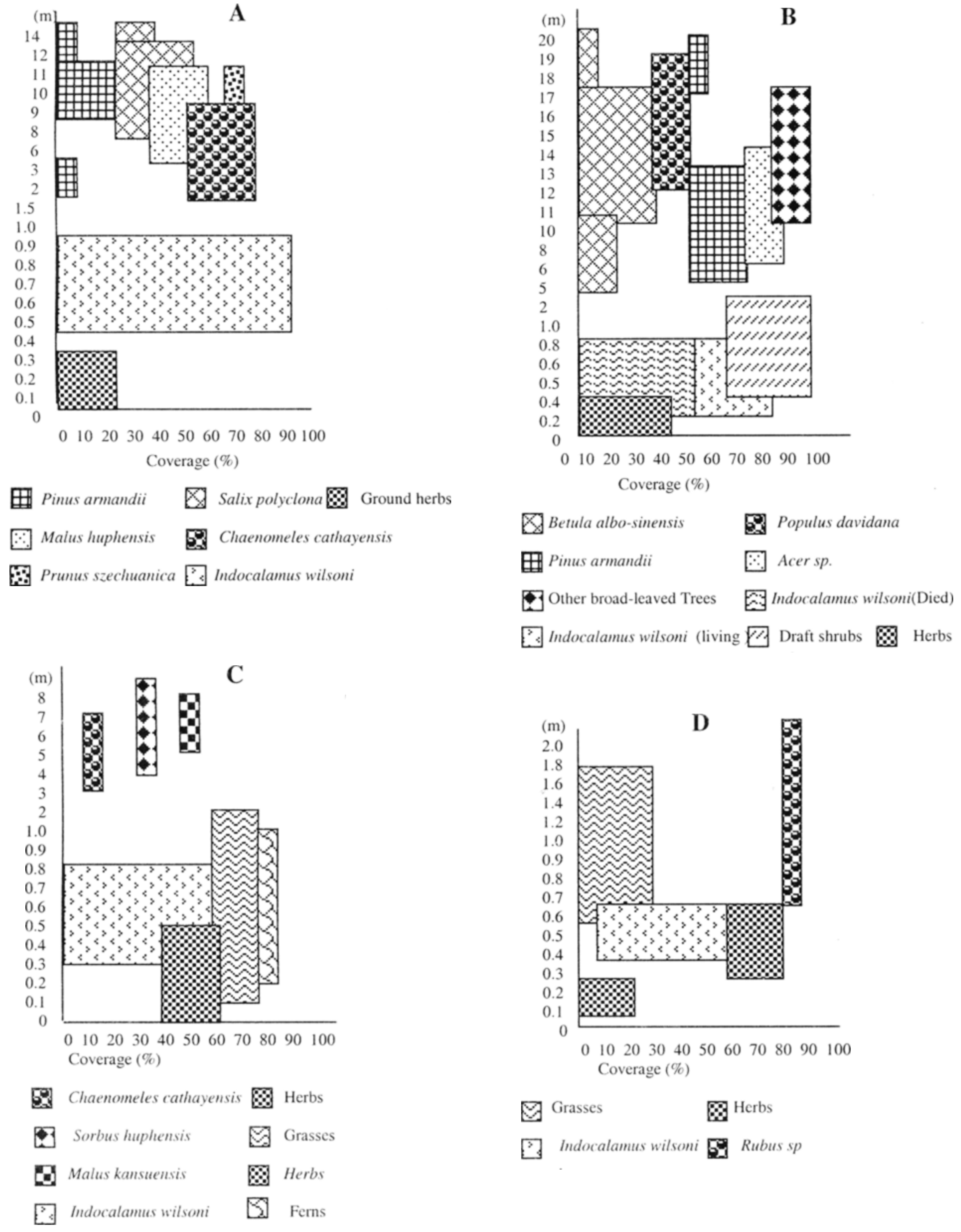

Fig. 4 (A-D). Coverage-profiles of four vegetation types with *Indocalamus wilsoni*

(A. Mixed forest, B. Deciduous broad-leaved forest, C. Open shrubs, and D. meadow)

Table 3. Living performance of *Indocalamus* in different vegetation types

Plot	Height (cm)	Density (culm/m²)	Coverage (%)
A	80-95	88	90-95
B	40-65	104*	60-80
C	60-75	73	60-70
D	40-60	55	40-50

A--mixed forest, B--broad-leaved forest, C.--open shrubs, D--meadow.
* including 30%-40% of died bamboos

The density of Indocalamus shows a special pattern in Plot B due to the flowering in the past two years. In our quadrats, the total density of bamboo is as higher as 104 culms/m^2, but 30%-50% of the culms died back after flowering in the past two years. Our investigation on its rhizome system shows that the flowering death temperately stimulated the vegetative regeneration of new shoots, which is very different from the most dominant subalpine bamboos from the genera of Fargesia in Shennongjia. The underground part of Frgesia is a sympodial system and the shoots can only be produced from its densely packed pseudo-rhizomes, while Indocalamus bears an amphpodial system which contains both spreading monopodia and packed sympodia. When Fargesia flowering, there are no new shoots are sprouted during the flowering period and its underground system usually decays away in the following years. When Indocalamus flowering, we noted its sympodium system ceased to generate new shoots, but its spreading rhizome was continually to extend and produce new shoots and new packed rhizomes. The extraordinary increase of the recruitment of new culms may be initially promoted by the gaps formed by flowered culms.

Although the vegetative growth of Indocalamus has not ceased immediately corresponding to the mass flowering, there is no evidence to indict that this mass flowering will not spread to over all of its habitats in Shennongjia. In fact, we checked out at the site that in some quadrats, over 90% of bamboo culms died after flowering and there was no any new shoots occurred in the year of 2000 and 2001, but we had not collected any bamboo seeds in the soil neither discovered seedling on the stands. So that, a further observation is needed to focus on whether its regeneration after flowering is established from seeds or compensated by new culms from its living rhizomes.

When a mountain bamboo species flowers, it is usually dieback over a large area and this moment we have no practicable methods to control the mass flowering and succeeding death (Yi 1994; Taylor *et al.* 1991; Akifumi. 1992; Huang 1998). However, our suggestion for the protection of this rare species is that *I. wilsoni* is very sensitive to the changes of upper canopy. Protecting its associated vegetation probably is one of the best ways to maintain its survivorship in the reserve.

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